

CLAIMS

1. An antenna apparatus comprising:

a dielectric substrate including a grounding conductor;

a minute loop antenna provided to be electromagnetically close

5 to said dielectric substrate, said minute loop antenna having a predetermined number N of turns and having a predetermined minute length, said minute loop antenna operating as a magnetic ideal dipole

when a predetermined metal plate is located closely to the antenna apparatus, said minute loop antenna operating as a current antenna

10 when said metal plate is located apart from the antenna apparatus; and

at least one antenna element connected to said minute loop antenna, said at least one antenna element operating as a current antenna,

wherein one end of said antenna apparatus is connected to a
15 feeding point, and another end of said antenna apparatus is connected to the grounding conductor of said dielectric substrate.

2. The antenna apparatus as claimed in Claim 1,

wherein said at least one antenna element is provided to be substantially parallel to a surface of said dielectric substrate.

20 3. The antenna apparatus as claimed in Claim 1 or 2, comprising two antenna elements.

4. The antenna apparatus as claimed in Claim 3,

wherein said two antenna elements are substantially linear and provided to be parallel to each other.

25 5. The antenna apparatus as claimed in any one of Claims 1 to 4, further comprising at least one first capacitor connected to at least

one of said minute loop antenna and said antenna element, said at least one capacitor series-resonates with an inductance of said minute loop antenna.

6. The antenna apparatus as claimed in Claim 5,
5 wherein said first capacitor is connected so as to be inserted into a substantially central point of said antenna element.

7. The antenna apparatus as claimed in Claim 5 or 6,
wherein said first capacitor is formed by connecting a plurality of capacitor elements in series.

10 8. The antenna apparatus as claimed in Claim 5 or 6,
wherein said first capacitor is formed by connecting a plurality of pairs of circuits in parallel, each pair of circuits being formed by connecting a plurality of capacitor elements in series.

9. The antenna apparatus as claimed in any one of Claims 1 to
15 8, further comprising an impedance matching circuit connected to the feeding point, said impedance matching circuit matching an input impedance of said antenna apparatus with a characteristic impedance of a feeding cable connected to the feeding point.

10. The antenna apparatus as claimed in any one of Claims 1
20 to 9,
wherein said minute loop antenna is provided so that a loop axis direction of the minute loop antenna is substantially perpendicular to the surface of said dielectric substrate.

11. The antenna apparatus as claimed in any one of Claims 1
25 to 9,
wherein said minute loop antenna is provided so that a loop axis

direction of the minute loop antenna is substantially parallel to the surface of said dielectric substrate.

12. The antenna apparatus as claimed in any one of Claims 1 to 9,

5 wherein said minute loop antenna is provided so that a loop axis direction of the minute loop antenna is inclined at a predetermined inclination angle with respect to the surface of said dielectric substrate.

13. The antenna apparatus as claimed in any one of Claims 1 to 12,

10 wherein the number N of turns of said minute loop antenna is substantially set to $N = (n - 1) + 0.5$, where n is a natural number.

14. The antenna apparatus as claimed in Claim 13,

wherein the number N of turns of said minute loop antenna is substantially set to $N = 1.5$.

15 15. The antenna apparatus as claimed in any one of Claims 1 to 14, further comprising:

at least one floating conductor provided to be electromagnetically close to said minute loop antenna and said antenna element; and

a first switch device for selectively switching said floating
20 conductor so as to or not to be connected to said grounding conductor, to change one of a directivity characteristic and a plane of polarization of said antenna apparatus.

16. The antenna apparatus as claimed in Claim 15, further comprising two floating conductors provided to be substantially
25 perpendicular to each other,

wherein said first switch device selectively switches said

respective two floating conductors so as to or not to be connected to said grounding conductor, to change at least one of the directivity characteristic and the plane of polarization of said antenna apparatus.

17. The antenna apparatus as claimed in any one of Claims 1
5 to 16, further comprising:

a first reactance element connected to at least one of said minute loop antenna and said antenna element; and

a second switch device for selectively switching said first reactance element so as to or not to be shorted, to change a resonance
10 frequency of said antenna apparatus.

18. The antenna apparatus as claimed in Claim 17,

wherein said second switch device includes a high-frequency semiconductor device having a parasitic capacitance when said second switch device is turned off, and

15 wherein the antenna apparatus further includes a first inductor for substantially canceling the parasitic capacitance.

19. The antenna apparatus as claimed in any one of Claims 1 to 16, further comprising:

a second reactance element having one end connected to at least
20 one of said minute loop antenna and said antenna element; and

a third switch device for selectively switching another end of said second reactance element so as to be grounded or not to be grounded, to change the resonance frequency of said antenna apparatus.

20. The antenna apparatus as claimed in Claim 19, further
25 comprising a third reactance element connected to at least one of said minute loop antenna and said antenna element.

21. The antenna apparatus as claimed in Claim 19 or 20,
wherein said third switch device includes a high-frequency
semiconductor device having a parasitic capacitance when said third
switch device is turned off, and

5 wherein the antenna apparatus further includes a second
inductor for substantially canceling the parasitic capacitance.

22. An antenna apparatus comprising:

a plurality of antenna apparatuses as claimed in any one of
Claims 1 to 21; and

10 a fourth switch device for selectively switching said plurality of
antenna apparatuses based on radio signals received by the plurality of
antenna apparatuses, and for connecting a selected antenna apparatus
to the feeding point.

23. The antenna apparatus as claimed in Claim 22,

15 wherein said fourth switch device grounds said unselected
antenna apparatuses.

24. The antenna apparatus as claimed in any one of Claims 1
to 23,

20 wherein said antenna apparatus is formed on a surface of said
dielectric substrate on which the grounding conductor is not formed.

25. The antenna apparatus as claimed in Claim 24,

wherein said minute loop antenna is formed on a further
dielectric substrate.

26. The antenna apparatus as claimed in Claim 25,

25 wherein said further dielectric substrate includes at least one
convex portion,

wherein said dielectric substrate includes at least one hole portion fitted into the at least one concave portion of said dielectric substrate, and

5 wherein said at least one convex portion of said further dielectric substrate is fitted into the at least one hole portion of said dielectric substrate, so that said further dielectric substrate is coupled with said dielectric substrate.

27. The antenna apparatus as claimed in Claim 25,
10 wherein said dielectric substrate includes at least one convex portion,

wherein said further dielectric substrate includes further at least one hole portion for being inserted and fitted into the at least one concave portion of said dielectric substrate, and

15 wherein said at least one convex portion of said dielectric substrate is inserted and fitted into the at least one hole portion of said further dielectric substrate, so that said dielectric substrate is coupled with said further dielectric substrate.

28. The antenna apparatus as claimed in Claim 26 or 27,
further comprising:

20 a first connection conductor formed on said dielectric substrate, said first connection conductor being connected to said antenna element; and

a second connection conductor formed on said further dielectric substrate, said second connection conductor being connected to said
25 minute loop antenna,

wherein said first connection conductor is electrically connected

to said second connection conductor when said dielectric substrate is coupled with said further dielectric substrate.

29. The antenna apparatus as claimed in Claim 28,

wherein said first connection conductor includes a first
5 conductor exposed section, which is a part of said first connection conductor and has a predetermined first area, said connection conductor being formed to be soldered so that said first connection conductor is electrically connected to said second connection conductor,
and

10 wherein said second connection conductor includes a second conductor exposed section, which is a part of said second connection conductor and has a predetermined second area, said second connection conductor being formed to be soldered so that said second connection conductor is electrically connected to said first connection
15 conductor.

30. A radio communication apparatus comprising:

said antenna apparatus as claimed in any one of Claims 1 to 29;
and

a radio communication circuit connected to said antenna
20 apparatus.